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E70 Chassis Dynamics

Initial Print Date: 10/06 Revision Date:

Chassis Dynamics

Model: E70

Production: From Start of Production

OBJECTIVES

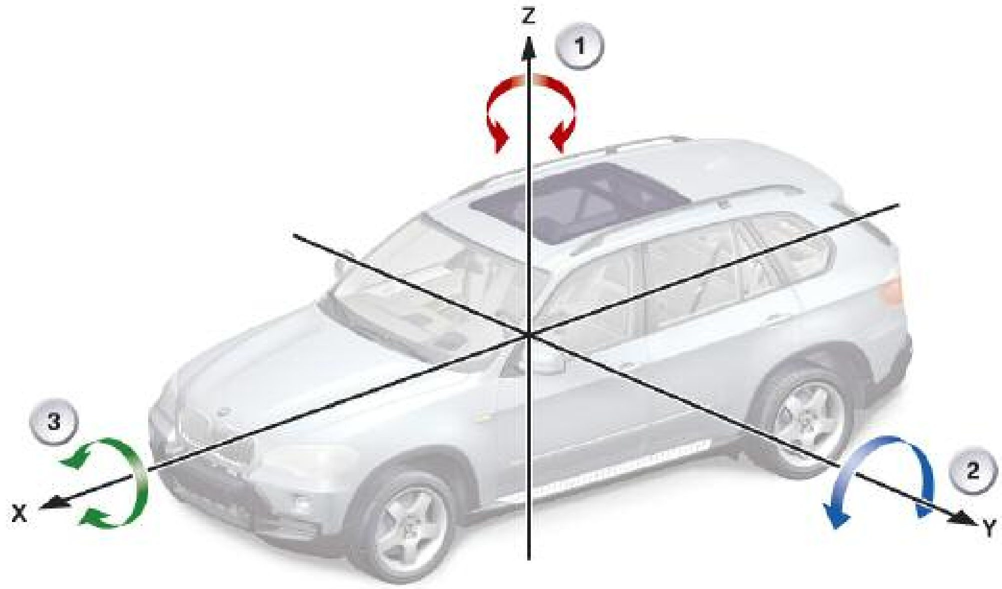
After completion of this module you will be able to:

- Understand Principles of Chassis Dynamics on the E70
- Describe Front and Rear Axle Changes

Driving Dynamics

Certain dynamic influences cause movements in the vehicle body. These movements can be subdivided into and represented as three categories.

A coordinate system can be constructed for this with three spatial coordinate axes, which allows this degree of freedom to be defined.



Index	Explanation	Index	Explanation
1	Yawing (about the vertical axis)	3	Rolling (about the longitudinal axis)
2	Pitching (about the vertical axis)		

- Longitudinal dynamics:
  The main direction of movement and the direction of travel is defined by the x or longitudinal axis of the coordinate system. Situations involving longitudinal dynamics, such as accelerating or braking, cause the vehicle to pitch and result in a movement about the y axis.
- Lateral dynamics:
  Lateral dynamics occur when the direction of movement is along the y or lateral axis, as is the case with steering or swerving. This causes, among other things, the vehicle to roll and move about the x axis.

Vertical Dynamics

If the body moves along the z or vertical axis, this is known as vertical dynamics and constitutes oscillating up and down movements of the body, e.g. when “kangarooing” the vehicle.

If there is still movement about the z or vertical axis of the vehicle, this is known as yawing. This type of movement occurs during understeer or oversteer and is demonstrated by drifting when the vehicle is being driven sportily, for example.

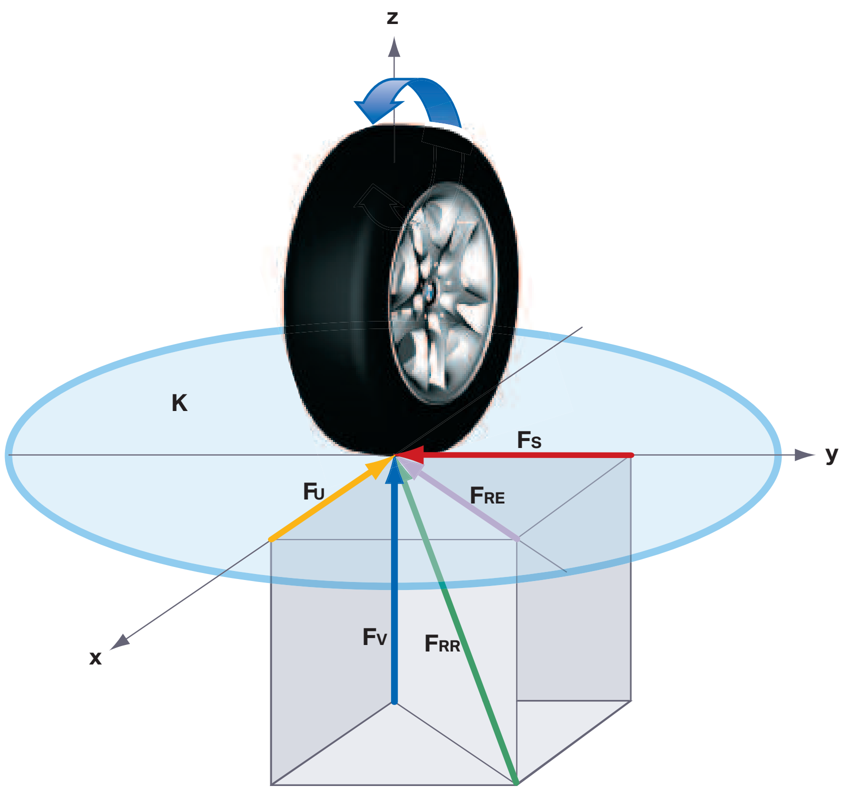
These basic dynamic characteristics depend specifically on the following vehicle dimensions.

Index	Explanation	Index	Explanation
1	Distance for the center of gravity from the road surface	3	Wheelbase
2	Track width		

The position of the center of gravity in the vehicle, its distance from the road surface, the wheelbase and the track width are decisive geometric parameters that shape the dynamic behavior of a vehicle.

Forces at the Wheel

The forces acting on the contact surface between the tire and the road are also subdivided into the three main directions.



Index	Explanation	Index	Explanation
K	Kamm's circle	F_V	Vertical tire force
F_u	Tangential tire force	F_{RE}	Resulting force on surface
F_S	Lateral tire force	F_{RR}	Resulting force in space

The vertical force is fundamental. This acts vertically to the road and corresponds to the load on the tire. The maximum transferable lateral and tangential tire forces are the product of the vertical force and the adhesion coefficient.

The radius of the Kamm's circle shows this mathematical relationship graphically. It is also possible to see the dependency between the tangential and lateral forces in the Kamm's circle.

Explanation of the Kamm's Circle using an Example

If a lateral tire force is acting on the wheel, a braking or accelerating force (tangential tire force) can only build up in a longitudinal direction up to the maximum total force (resulting force on surface). When this is reached, the wheel locks or spins.

Conversely, only a limited lateral cornering force (lateral tire force) can be achieved under braking. If this is exceeded, the wheel slips in a lateral direction. This causes the vehicle to skid. If a braking force takes effect, the full lateral cornering force can be established in accordance with the radius of the Kamm's circle.

In the same way, the full braking or acceleration force can be established when the vehicle is driving straight ahead (again according to the radius).

This relationship shows that acceleration or braking that is too rapid under cornering can cause the vehicle to skid, as any longitudinal force on the wheel, whether it serves to accelerate or brake, inevitably results in a failure of the lateral cornering forces.

The radius of the Kamm's circle depends on the friction coefficient between the tire and the road, i.e. on the tire, the road surface and the road conditions. If the road is wet, for example, the radius is considerably smaller than if the road is dry.

Interrelationships between the effects of the dynamic driving systems

The possible effectiveness of modern dynamic driving systems is based only on the interrelationship between the tires and the road.

In order to classify and differentiate between the many systems in the E70, they are described in three separate Reference Information documents:

- E70 longitudinal dynamics systems - The following dynamic driving systems act on the tangential wheel forces:
  - ABS
  - ASC
  - DSC
  - MSR

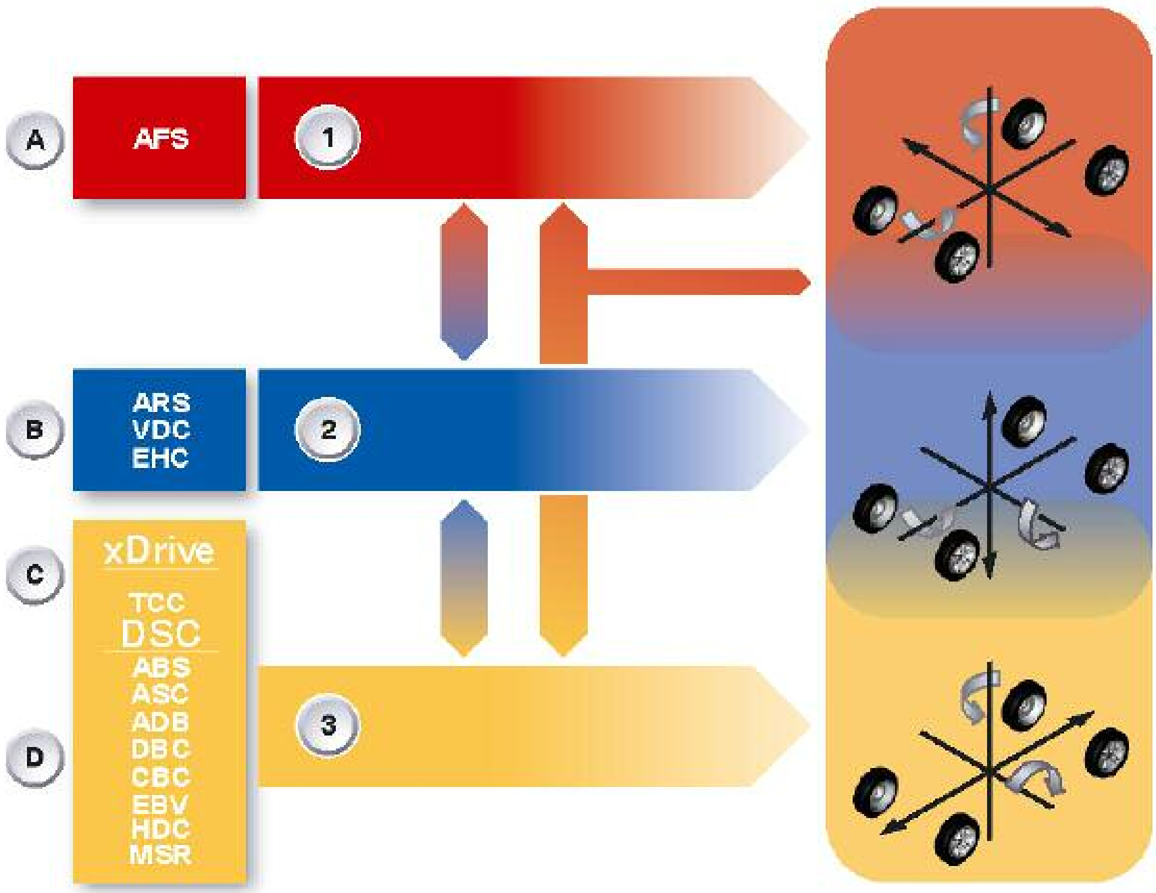
These influence the translatory (longitudinal) movement along the x axis and the rotational movement about the y axis.

- E70 lateral dynamics systems - Lateral wheel forces are primarily generated by the steering angle, i.e. they are influenced by the power steering and Active Steering on the front axle. The most significant effect occurs as a rotational movement about the z axis.
- E70 vertical dynamics systems - The following essentially act upon the vertical wheel forces and the wheel contact forces:
  - VDC
  - EHB
  - ARS

This affects the translatory movement along the z axis and, depending on the system, the rotational movement about the x axis for ARS or about the y axis for EHC.

Furthermore, the rotational movement about the z axis due to altered wheel contact forces is also influenced by ARS (actual dynamic significance of the anti-roll bar).

The complexity of the relationships and the reciprocal influencing of the tire forces and therefore the vehicle movement should be made clearer by the following graphic.



Index	Explanation	Index	Explanation
1	Lateral tire forces/lateral dynamics	B	Ride comfort
2	Vertical tire forces/vertical dynamics	C	Traction
3	Tangential tire forces/longitudinal dynamics	D	Safety when braking and accelerating
A	Handling		

E70 Chassis and Suspension

Through intelligent design layout and optimum package space utilization on the E70, the basis has been created for distinctly increasing the driving dynamics while improving comfort and vehicle handling. At virtually identical wheel loads, a greater track width and a larger wheelbase have been realized compared to the predecessor, the E53.

While essentially retaining the same center of gravity, the best prerequisites have been created for meeting the target "Best in segment" with the new chassis and suspension of the E70.

Index	Explanation	Index	Explanation
1	Center of gravity	3	Wheelbase
2	Track width, front		

Comparison

	E53	E70
Front axle	Double pivot spring strut front axle	Double wishbone front axle
Suspension/damping, front	Steel spring or air spring	Steel spring
Anti-roll bar, front	Mechanical	Mechanical or Hydraulic
Rear axle	Integral IV	Integral IV
Suspension/damping, rear	Steel spring or air spring	Steel spring or air spring
Anti-roll bar, rear	Mechanical	Mechanical or Hydraulic
Brake, front	Brake disc diameter up to 356 mm	Brake disc diameter up to 365 mm
Brake, rear	Brake disc diameter up to 324 mm	Brake disc diameter up to 345 mm
Parking brake	Drum brake, mechanical	Drum brake, with electro-mechanical parking brake (EMF)
Wheels/tires	Standard tires	Run flat tires
Steering	Power steering or Servotronic	Power steering or active steering

	E53	E70
Unladen weight (kg)	2070 kg	2085 kg
Center of Gravity	678 mm	680 mm
Track width, front	1576 mm	1644 mm
Track width, rear	1576 mm	1650 mm
Wheelbase	2820 mm	2933 mm

Track Width, General

The size of the track width at the front and rear has a decisive influence on the cornering characteristics of the vehicle and its tendency to roll.

- The track width should be as large as possible, however, it cannot exceed a defined value in relationship to the width of the vehicle.
- The fully deflected (spring compressed) wheel turned at full lock on the front axle must not scrape or snag in the wheel arch cutout.
- A certain degree of clearance for fitting snow chains is required on the drive axle (irrespective of whether this is the front, rear or both axles).
- The wheels must not make contact with any chassis or body parts when the suspension springs fully compress and rebound.

Wheelbase, General

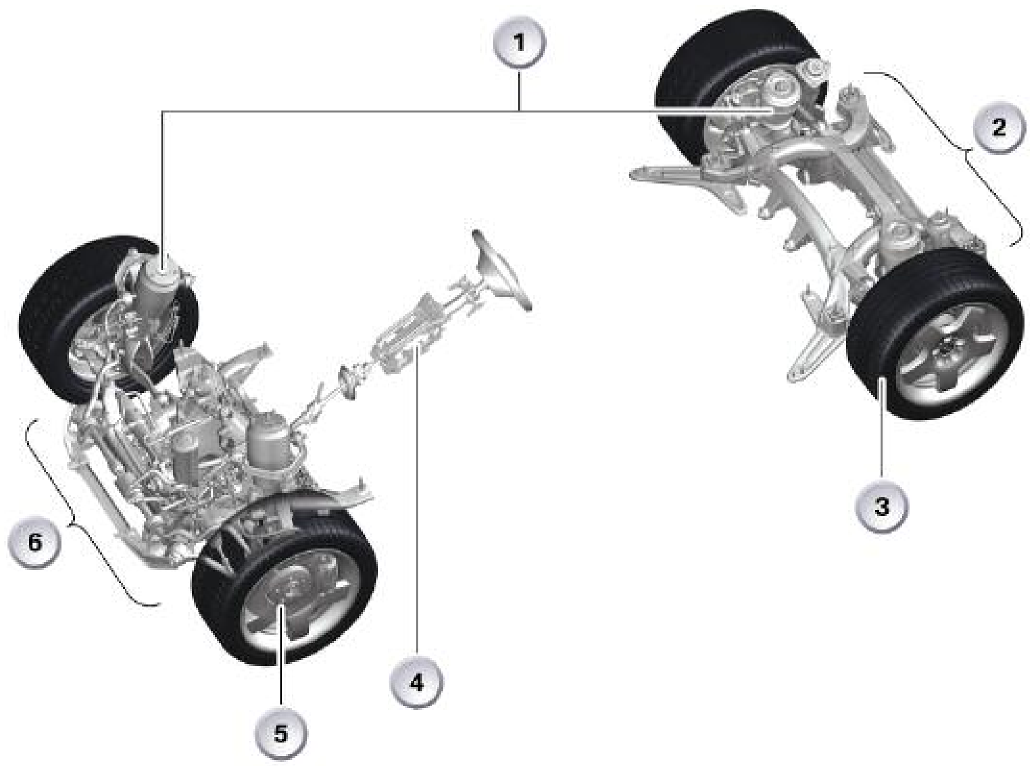
The wheelbase -measured from the center of the front axle to the center of the rear axle has a decisive influence on the vehicle handling properties.

A large wheelbase compared to the length of the vehicle permits favorable accommodation of the vehicle occupants between the axles and reduces the influence of the vehicle load on the overall load distribution. Short body overhang at the front and rear reduces the pitching tendency.

A short wheelbase, on the other hand, provides favorable cornering characteristics, i.e. a smaller turning circle at the same steering lock angle.

The outstandingly balanced values on the E70 result in safe, superior and agile vehicle handling characteristics that represent the standard in the SAV class (SAV = Sports Activity Vehicle) also for the future. These technical data are the prerequisite for achieving the top position in its class. In terms of driving dynamics, the E70 will assume a leading position without forfeiting driving and rolling comfort compared to the competition (with comparable equipment).

Chassis and Suspension Overview



Index	Explanation	Index	Explanation
1	Spring/damper	4	Steering
2	Rear axle	5	Brakes
3	Wheels/tires	6	Front axle

Front Axle

For the first time on a BMW vehicle, a double wishbone front axle is used on the E70. The outstanding driving dynamics, the excellent driving comfort as well as the stable straight-ahead running properties are factors of this design solution that contribute to a high degree of driving pleasure and safety while making the vehicle ideal for every day use and providing the most relaxing drive on long journeys.

Rear Axle

Compared to the E53, the further-developed integral IV rear axle in the E70 is characterized by further improved driving dynamics without compromising comfort and driving safety. This axle design on the E70 has made it possible to increase the width and depth of the load area.

The result is a considerably larger and more functional load space (third row of seats) particularly through the use of the single-axle air spring (rear axle air suspension). This design layout guarantees brilliant road handling characteristics irrespective of the vehicle load and at a constant ride height.

Dampers/Suspension

In the E70, the range of spring/damper units extends from steel springs with conventional dampers through to the new vertical dynamic control (VDC) that, in addition to the electronically controlled dampers, also allows a combination of a 1-axis air spring on the rear axle. This 1-axis air spring is compulsory on vehicles with 8-cylinder engines and/or a third row of seats.

Brakes

The brake system installed on the E70 is a further-developed high performance brake system with newly adapted dimensions for the E70. The service brake is based on the conventional design while in contrast to the E53 the parking brake features an electro-mechanical parking brake system (EMF).

Steering

The E70 is available with two steering system variants:

- Hydraulic power steering
- Active steering (AL)

Both steering systems are adapted to the diverse and varied possible applications of the E70 and the active steering is used for the first time in an all-wheel drive vehicle.

Wheels and Tires

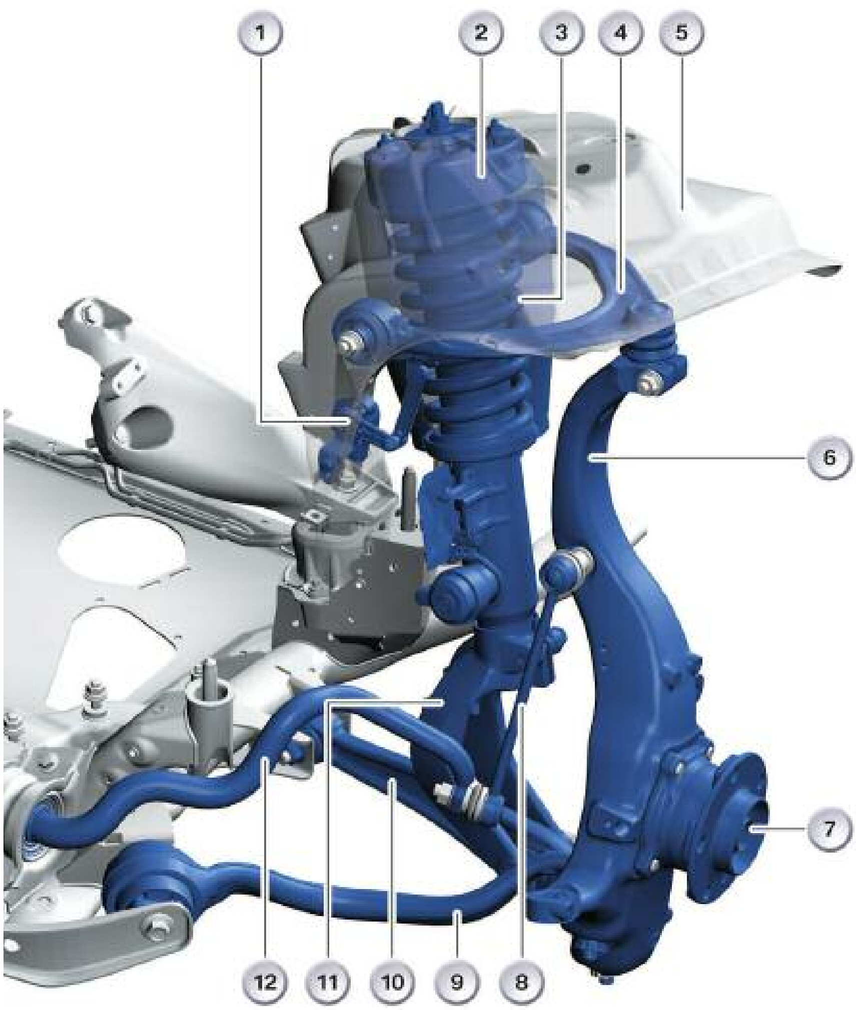
The E70 is the first all-wheel drive vehicle (X-family) that is equipped with a run flat safety package as standard.

General

The chassis and suspension system is divided into the following main components:

- Front axle
- Rear axle
- Damping/suspension
- Brakes
- Steering
- Wheels/tires

Front Axle



Index	Explanation
1	Ride-height sensor
2	Mount
3	Spring strut
4	A-arm, top
5	Spring strut support
6	Swivel bearing
7	Wheel bearing
8	Stabilizer link
9	Tension strut with hydraulic mount
10	Control arm, bottom
11	Spring strut fork
12	Anti-roll bar

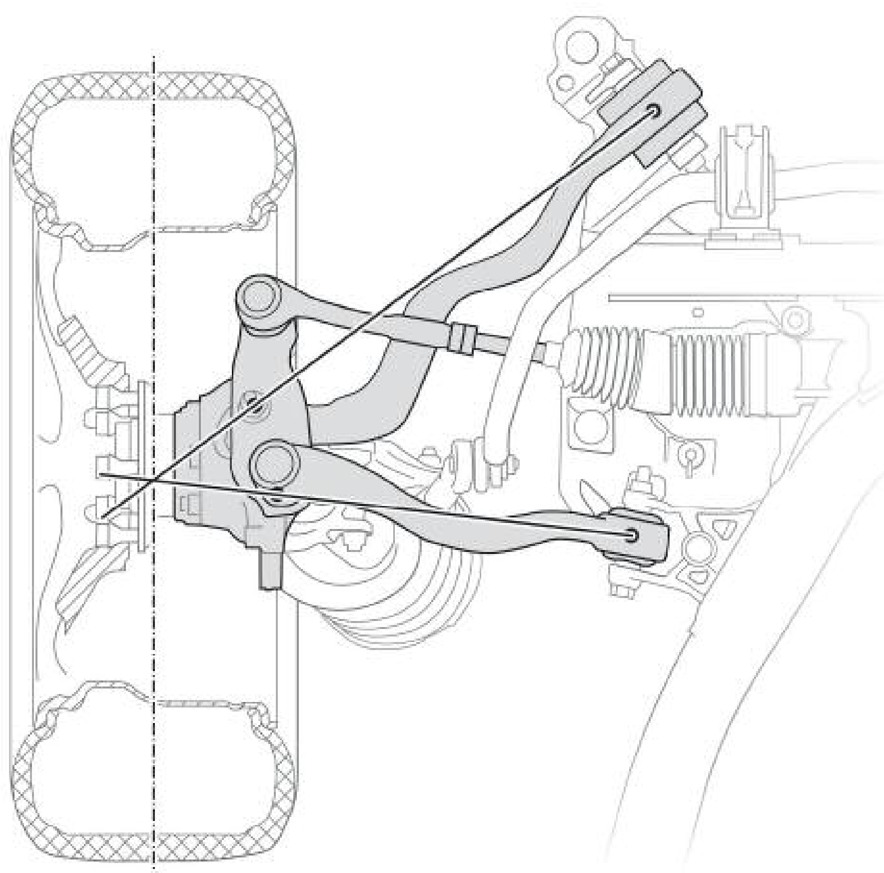
The introduction of a second control arm level for wheel control, which is arranged above the wheel, results in additional degrees of freedom for the kinematics of the front axle as well as for the suspension/damping compared to other designs such as a McPherson strut axle.

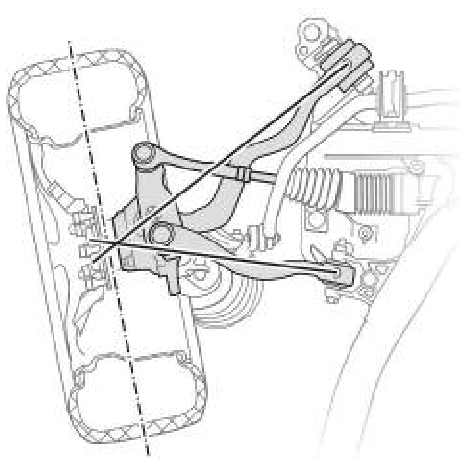
Components with special materials (see graphic on previous page):

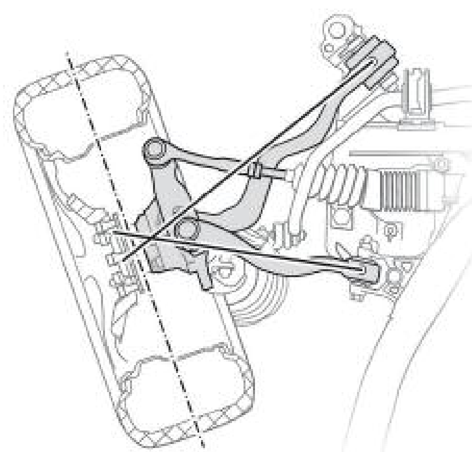
- The forged aluminum swivel bearing (6) with the 3rd generation wheel bearing (7) Semi-trailing arm connected via steel bushes/tapered screw connection to the swivel bearing. Attention: Refer to special repair instructions!
- The A-arm at the top (4) is made from forged aluminum and the cylindrical joint pin is clamped in the swivel bearing (6).
- Tension strut with hydraulic mount (9) and bottom control arm (10) are forged steel components while the bottom control arm bears the spring strut (3) by means of the cast steel spring strut fork (11).
- The front axle subframe is a welded steel structure with an aluminum thrust panel for maximum lateral stiffness with service openings.

Virtual Pivot Point

The steering pivot axis of the wheel suspension is now formed by a joint at the top A-arm and the virtual pivot point of the lower arm level as known from the spring strut or McPherson axle.







The steering pivot axis is therefore freely selectable and can be positioned such as to produce a small disturbing force lever arm with sufficient weight recoil. This disturbing force lever arm is decisive for transmitting the irregularities on the road surface to the steering wheel. The upper and lower arm level now move simultaneously in response to wheel lift so as to swivel the wheel during spring deflection in such a way that the negative camber with respect to the road is not reduced as much as on a McPherson strut suspension setup.

Since the two control arm levels undertake the wheel control, the damper is no longer subjected to transverse forces. This makes it possible to do without a roller bearing assembly as the strut mount on the spring strut support. Instead of this conventional roller bearing, two PUR discs (hybrid bearing) are fitted above and below the spring strut mount.

Due to the substantially lower friction, the damper can respond more sensitively to unevenness of the road surface. Due to the lack of transverse forces, the piston rod can be made thinner, resulting in a similar displacement volume in the push and pull direction of the damper. This serves to improve the design layout of the damper and is the pre-requisite for the innovative damper control system - vertical dynamic control (VDC).

By connecting the anti-roll bar via the stabilizer link to the swivel bearing, the torsion in response to body roll motion is equivalent to the total wheel lift from the inside to the outside of the curve (in other suspension setups, the anti-roll bars are connected to a control arm and therefore achieve only a fraction of the torsion angle). Despite being highly effective, this high degree of torsion allows for the anti-roll bar to be made relatively thin which has a favorable effect on driving comfort and dynamics as well as saving weight.

Cast Aluminum Spring Support (body side)

The spring support on the E53 was not yet made of aluminum but rather from a conventional sheet metal shell construction. On the E70, a cast aluminum spring support is used for the first time in the front end of the X-Series with the following advantages:

- Reduced weight through intelligent lightweight construction
- Improved driving dynamics thanks to higher degree of stiffness
- Less components therefore reduced manufacturing expenditure

The cast aluminum spring support takes up the forces from the chassis and suspension and directs them into the car body. Both the spring strut as well as the upper control arm are secured to the cast spring support. The component must exhibit a high degree of stiffness for this purpose. This is achieved by optimum material distribution by ensuring material is only accumulated where necessary.

The spring support therefore represents an important contribution to controlling driving characteristics as it takes up both static and dynamic wheel forces. Since, with the cast construction, it is possible to integrate many individual functions and components in one single component, compared to the conventional shell construction, this setup is distinctly more compact while making a significant contribution to reducing weight.

- The cast aluminum lightweight construction reduces the weight by approximately 50% compared to the conventional sheet steel construction.
- More useful package space compared to conventional sheet steel construction - 80 mm shorter front end
- Function-compliant design with specific local stiffening points adding to lightweight construction
- Integration of various brackets for mounting units etc. in the cast aluminum spring support with add-on parts

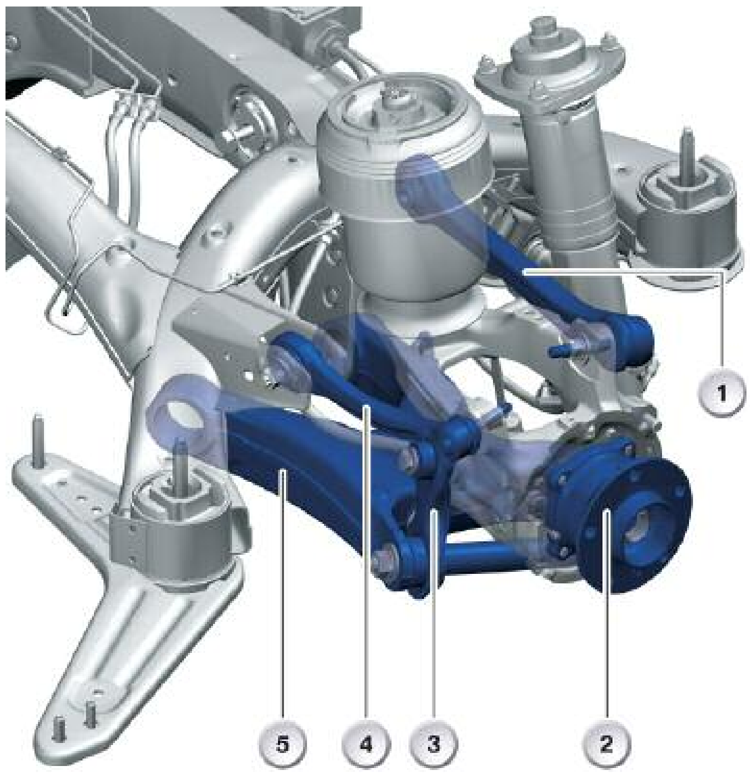
The cast aluminum spring support is connected to the neighboring steel components (e.g. engine support) by means of a rivet-adhesion structure. The structure is of lower weight while making it possible to reduce the number of parts (no additional sheet metal brackets). Nevertheless, the vehicle body is more stable and torsionally rigid while increasing local stiffness. This design arrangement has a positive effect on improved driving dynamics.

Front axle data	E70
Wheel	R18 8.5J X 18 EH2 + IS46
Tires	255/55 R18
Rim offset (mm)	46
Tire radius (mm)	338
Wheelbase (mm)	2933
Track width (mm)	1644
Camber	-0° 20’ ±20’
Camber difference	0° ±30’
Total toe-in	10’ ±6’
Wheel axle angle	0° ±4’
Kingpin offset (mm)	-8.4
Toe-out difference angle	2.1° ±30’
Caster angle	7° 48’ ±30’

Rear Axle

The integral IV rear axle fitted in the E70 fulfills the primary function of the running gear and wheel control in a unique way while making a significant contribution to driving dynamics.

Safety functions are defined by the superior vehicle control characteristics. Effective de-coupling of the road and drive train guarantees outstanding levels of acoustic and vibration comfort.



Index	Explanation	Index	Explanation
1	Control arm	4	Upper radius arm
2	Wheel carrier	5	Swinging arm
3	Integral link		

The principle of the integral IV rear axle makes it possible to resolve the conflict between driving dynamics and comfort. The dynamic and drive forces applied through the wheel contact point into the wheel suspension are taken up by the wheel carrier, rear axle carrier and four control arms. The design layout reduces the flexible pulling action in the wheel carrier and therefore enables lengthways damping of the wheel control, which is important for rolling comfort, by means of soft front link brackets on the rear axle carrier.

Thanks to the position of the spring on the wheel carrier, it is no longer necessary to support the weight of the vehicle on the rubber mounts on the rear axle carrier.
The optimum lengthways damping and the favorable spring position facilitate effective isolation of rolling and drive noise while significantly contributing to the refined smooth and quiet vehicle running characteristics.

The rear axle of the E53 has undergone consistent further development for the E70 and adapted to the requirements of the larger dimensions, higher overall weight, increased power/torque, the BMW run flat safety system and the demanding objectives in terms of driving dynamics and comfort. The main criteria that governed the selection of materials included component weight, production process (cold forming, casting properties, welding properties), strength and deformation characteristics as well as corrosion resistance.

The resulting advantages include:

Outstanding driving dynamics, further increased compared to the E53, without compromising comfort and driving safety.

- Distinctly larger and more functional load area by increasing the effective load width and depth.
- Level control (1-axis air suspension) ensures constant ride-height and driving characteristics irrespective of the vehicle load.

Rear axle data:

Rear axle data	E70
Wheel	R18 8.5J X 18 EH2 + IS46
Tires	255/55 R18
Rim offset (mm)	46
Tire radius (mm)	338
Wheelbase (mm)	2933
Track width (mm)	1650
Camber	-1° 30’ ±15’
Camber difference	0° ±30’
Total toe-in	10’ ±6’
Wheel axle angle	0° ±4’

Damping/Suspension

The E70 is equipped with steel springs and conventional dampers as the standard suspension setup. In addition, the following combinations are available:

- Standard suspension with sport suspension setup
- Standard suspension with 1-axis air spring
- Adaptive drive with steel springs and VDC dampers
- Adaptive drive with 2 steel springs and 1-axis air spring and VDC dampers

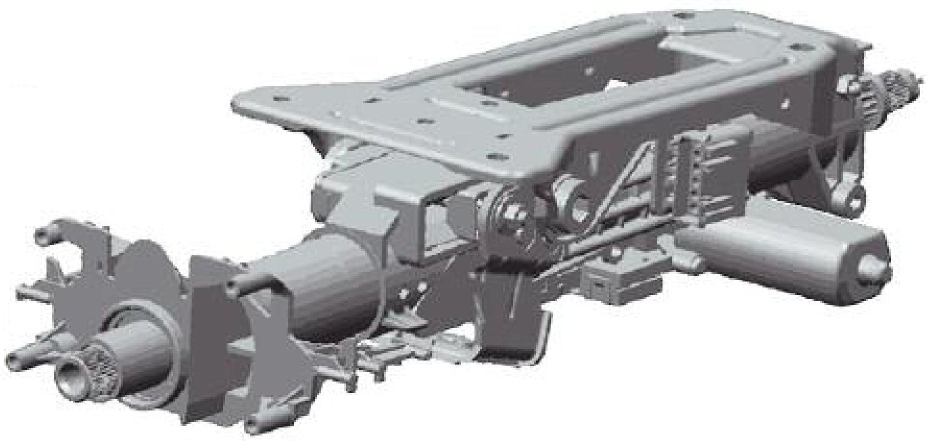
Brakes

In terms of function, an optimized high performance brake system is used on the E70. Floating brake calipers are fitted on the front and rear axle. The brake system in the E70 features the known brake wear monitoring system for the CBS indicator.

Front axle	N52B30 US+LA	N62B48 US+LA
Brake caliper housing	GGG	GGG
Brake caliper/piston diameter [mm]	60	60
Brake disc thickness [mm]	30	30
Brake disc diameter [mm]	332	348
Size	17’’	18’’
Rear axle	**N52B30 US+LA**	**N62B48 US+LA**
Brake caliper housing	AL	AL
Brake caliper/piston diameter [mm]	44	44
Brake disc thickness [mm]	20	24
Brake disc diameter [mm]	320	345
Size	17’’	18’’
Parking brake	Duo-Servo 185x30 (EMF)	

Steering

The E70 is available with an electrically adjustable steering column as standard equipment.



Adjustment range of manual steering column:

- Vertical +/-25 mm
- Horizontal +/-20 mm

Adjustment range of electrical steering column:

- Vertical +/-25 mm
- Horizontal +/-20 mm

A special feature of the electrically adjustable column is that only one electric motor is required for the height and tilt adjustment and this motor is connected to a special gear mechanism for both adjustment axes.

Index	Explanation	Index	Explanation
1	Normal position (0-mm)	5	Crash position (80-mm compressed)

A special feature of the adjustable steering column on the E70 is the innovative crash system consisting of a crash adapter and crash tube. In the event of a crash, the impact energy is progressively reduced for the driver by the crash tube breaking open and deforming, thus providing the advantage of reduced stress on the occupants in the event of a crash (integral part of the 5-star philosophy at BMW). In addition, the lower and center steering shaft collapses during the crash thus preventing penetration of the steering column into the passenger compartment.

Advantages of this new steering column:

- Low risk of injury in the event of a crash
- Thanks to its versatile adjustment options, the steering column provides excellent ergonomic positioning for the driver.

Wheels and Tires

For the first time, an X-vehicle is equipped as standard with the run flat safety system. Tyre damage and tire failure are among the most feared driving experiences.

The BMW run flat safety system:

- Warns the driver in good time of imminent tire pressure loss so that counter-measure can be taken.
- Allows the journey to be continued for a defined distance even in the event of complete loss of tire pressure.
- Keeps the tire safely on the rim even in the event of sudden tire pressure loss at high speed.

The system consisting of the run flat tires (RSC), rims with extended hump (EH2+) contour and the electronic monitoring system (TPMS), renders a spare wheel or space-saver wheel, breakdown kit or vehicle jack unnecessary and this creates more storage space in the luggage compartment while also saving weight.

Extended Hump Rims (EH2+)

The specially shaped rim humps ensure that the RSC tire cannot detach from the rim even in the case of sudden tire pressure loss. This means substantially greater safety particularly when driving at high speed and on winding roads.

Tire Failure Indicator RPA

The electronic monitoring system RPA monitors the tire pressure by constantly comparing the wheel speeds (dynamic rolling circumference). A warning lamp informs the driver of any irregularities that occur due to the loss of tire pressure. The system triggers a warning as from a vehicle speed of 25 km/h and at a pressure drop of more than 30%.

The RPA system is designed to signal a sudden and excessive loss of pressure and does not exempt the driver from regularly checking the tire pressure. After changing the tire pressure or after changing a tire, the RPA must be re-initialized in order to restore the target values with the correct tire pressure.

The entire safety package consists of three components:

- RSC tires with emergency running properties
- Extended hump rims (EH2+)
- Tire Pressure Monitoring System (TPMS).

RSC tires with emergency running properties

With its reinforced side walls, additional strip inserts and heat-resistant rubber mixtures, even when completely depressurized, the "self-supporting tire" makes it possible to continue the journey for a limited distance at a maximum speed of 80 km/h. This means each tire is also its own spare wheel.

The maximum range after complete tire pressure loss is:

- approximately 250 km at low vehicle load
- approximately 150 km at medium vehicle load
- approximately 50 km at high vehicle load

In the case of slow pressure loss, i.e. representative of approximately 80% of all tire failure cases, the remaining range as from the RPA warning is approximately 2000 km. ABS, ASC and DSC remain fully operational even in the event of complete tire pressure loss.

When driving with a run flat tire with no pressure, the optionally available adaptive drive system automatically distributes the vehicle weight over the remaining wheels so as to relieve the load on the depressurized tire with the aim of achieving the highest possible range for continued operation.